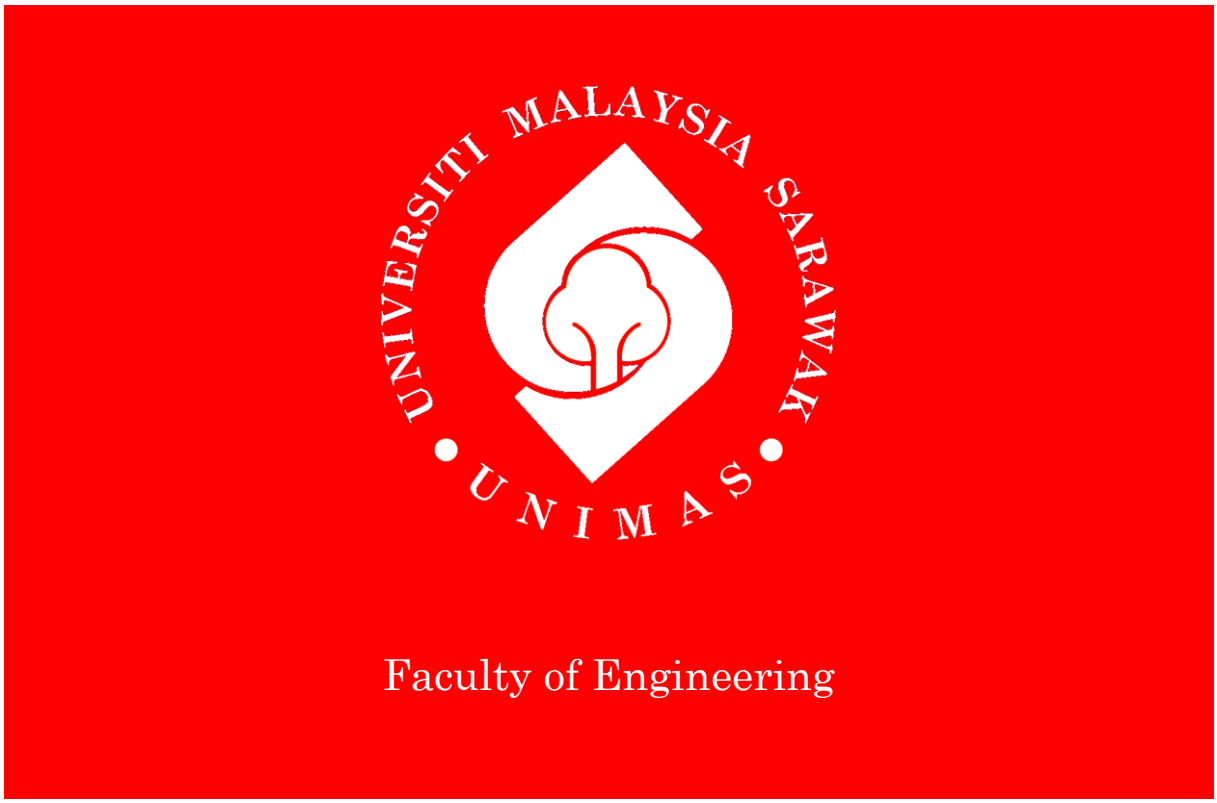

DESIGN AND IMPLEMENTATION OF SPACE VECTOR PULSE WIDTH MODULATION (SVPWM) FOR HARMONIC REDUCTION FOR THREE PHASE INVERTER SYSTEM

Christie Mijen

Bachelor of Engineering (Hons)

Electrical and Electronics Engineering

2018

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

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Final Year Project Report ☑

Masters ☐

PhD ☐

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DESIGN AND IMPLEMENTATION OF SPACE VECTOR PULSE WIDTH MODULATION (SVPWM) FOR HARMONIC REDUCTION FOR THREE PHASE INVERTER SYSTEM

CHRISTIE MIJEN

A dissertation submitted in partial fulfilment

of the requirement of the degree of

Bachelor of Engineering (Hons)

Electrical and Electronics Engineering

Faculty of Engineering

Universiti Malaysia Sarawak

2018

To beloved family and friends

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Abstract

Alternating current (AC) and direct current (DC) are biggest part in electrical world. Everything is empowered by either AC or DC as the source. When AC and DC are needed in one system, conversion technique is used in between them for a particular system to work. Conversion of DC to AC needs inverter while AC to DC is rectifier. In this project, issue will be focused on inverter, specifically three phase inverter.

Problem started to arise when total harmonic distortion is higher during the conversion. Changing DC to AC gives more noise at the output. This noise or distortion can bring many problems to the equipment that being supplied. It can shorten the lifespan of an equipment.

This report presents a simulation and development of three phase inverter by using space vector pulse width modulation (SVPWM) as control system to reduce harmonics. The model was implemented using MATLAB/Simulink with the block set and also M-file. Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET) was used as switches. In three phase inverter, a Direct Current (DC) source is supply and converted to Alternating Current (AC) by switching the switches on each leg to ON and OFF state based on the control system. The SVPWM is used as the control system to control the switching scheme of the MOSFET in this project.

The result of the simulation and experimental will be compared by using the sinusoidal wave produced. The output will be monitored, discussed and compared. SVPWM can provide lower total harmonics distortion compare to the other technique.

Abstrak

Arus bergantian (AC) dan arus terus (DC) adalah bahagian terbesar dalam dunia elektrik. Semuanya diberi kuasa oleh AC atau DC sebagai sumber. Apabila AC dan DC diperlukan dalam satu sistem, teknik penukaran digunakan di antara mereka untuk sistem tertentu untuk berfungsi. Penukaran DC ke AC memerlukan penyongsang manakala AC ke DC adalah penerus. Dalam projek ini, isu akan difokuskan pada penyongsang, khususnya tiga inverter fasa.

Masalah mula timbul apabila penyelewengan jumlah harmonik lebih tinggi semasa penukaran. Mengubah DC ke AC memberi lebih banyak bunyi pada output. Bunyi atau gangguan ini boleh membawa banyak masalah kepada peralatan yang dibekalkan. Ia boleh memendekkan jangka hayat peralatan.

Laporan ini membentangkan simulasi dan pembangunan tiga inverter fasa dengan menggunakan modulasi lebar denyut vektor ruang (SVPWM) sebagai sistem kawalan untuk mengurangkan harmonik. Model ini dilaksanakan menggunakan MATLAB / Simulink dengan set blok dan juga M-file. Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET) digunakan sebagai suis. Dalam tiga fasa penyongsang, sumber Terus Langsung (DC) adalah bekalan dan ditukar kepada Garis Alternatif (AC) dengan menukar suis pada setiap kaki ke keadaan ON dan OFF berdasarkan sistem kawalan. SVPWM digunakan sebagai sistem kawalan untuk mengawal skema pertukaran MOSFET dalam projek ini.

Hasil simulasi dan eksperimen akan dibandingkan dengan menggunakan gelombang sinusoidal yang dihasilkan. Hasil keluaran akan dipantau, dibincangkan dan dibandingkan. SVPWM boleh memberikan penyelewengan harmonik jumlah yang lebih rendah berbanding dengan teknik lain.

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List of Abbreviations

AC	−	Alternating Current
BJT	−	Bipolar
CSI	−	Current Source Inverter
DC	−	Direct Current
DSP	−	Digital Signal Processing
FPGA	−	Field-Programmable Gate Array
HVDC	−	High Voltage Direct Current
IGBT	−	Insulated Gate Bipolar Transistor
LED	−	Light Emitting Diode
MOSFET	−	Metal-Oxide-Semiconductor Field-Effect Transistor
PSCAD	−	Power System Computer Aided Design
PWM	−	Pulse Width Modulation
RMS	−	Root-Mean-Square
SVPWM	−	Space Vector Pulse Width Modulation
THD	−	Total Harmonic Distribution
UPS	−	Uninterruptible Power Supply
VFD	−	Variable Frequency Drive
VSI	−	Voltage Source Inverter

CHAPTER 1

INTRODUCTION

1.1 Background Research

In today's world, technology is one of the biggest or hottest issue people tries to conquer. The evolution of the technology in every element has made human's life easier day by day. Power electronics technology is one of the technology that fast expanding in industrial since the advance in power semiconductor technology and microprocessor control. Power electronics technology is the technology associated with the efficiency of the conversion, controlling, and conditioning of electric power. Basically, power electronics deals with power conversion using power semiconductor devices in a highly efficient, reliable and cost-effective way.

Direct current (DC) and alternating current (AC) are two different form of current flow. DC flows in one direction on the other hand AC flow periodically. To transform AC characteristics to DC, a rectifier is needed while DC to AC require an inverter. Inverters as the name mention, are power electronics converters which convert DC to AC sources whether in single phase or three phase based on the modelling.

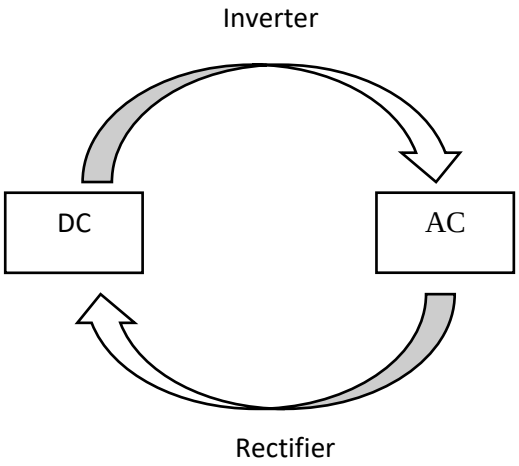

Figure 1. 1 DC AC conversion

Inverters are normally practiced in renewable energy resources such in solar system since solar system produce DC and store in batteries before supplied to the equipment. Other applications are AC motor drive system, electric power transmission systems, active filters and electric power quality improvement, active power factor correction systems, and uninterruptible power supply systems (UPS).[1] Inverters can be categorised by their input source, voltage or current input.[2] Voltage source inverter (VSI) used voltage as input source while current source inverter (CSI) used current.[2]

Inverter is categorised as an electronic generator based on its function, then inverter can control the root mean square (RMS) value and the frequency of the output voltage fundamental component. Pulse width modulation (PWM) is the control technique that accepted universally. SVPWM is one of the commonly used PWM method where it involved the vectors to generate the pulses. SVPWM is one of the well-known technique due to its ability and efficiency with low harmonics distortion to generate sinusoidal voltage.[3] SVPWM is solely the digital implementation of PWM modulators in a simple explanation.[4]

1.2 Problem Statement

The largest problem in power quality is harmonic distortion. Harmonic distortion is divided into two of the harmonic which are voltage and current harmonics. Harmonic

currents produced by the harmonics contained in the supply voltage depending on the types of loads such as resistive load, capacitive load and inductive load. These harmonics can be generated from the source side or load side. Non-linear load causes the harmonics at the load side. Hence, shorten the lifespan of equipment and reduce the efficiency. Voltage harmonics are frequently due to current harmonics. Source impedance from the current harmonics will caused the output voltage of the voltage source distorted. If the source impedance of the voltage source is small, current harmonics will cause only small voltage harmonics. In order to make the applications operate smoothly, there are several modulation techniques that are used to cater the output variable that have maximum basic component with minimum harmonic and less switching losses. In this project, SVPWM is used as a modulation technique.

1.3 Research Objective

The main objectives of this project are:

i. To model and simulate the proposed three phase inverter with a suitable topology.
ii. To develop a control strategy of the proposed three phase inverter circuit.
iii. To design and fabricate of a prototype three phase inverter circuit.
iv. To analyse and verify the total harmonic distortion (THD) and the performances of the proposed three phase inverter and its control system.

1.4 Project Scope

In order to fulfil the objectives stated, several steps must be taken. These steps include both software development and hardware implementation.

First step will be established the proposed three phase inverter to identify its electrical characteristics. The three phase inverter will be simulated in MATLAB Simulink before further test. Then, the SVPWM control algorithm will be modelled in MATLAB based on few previous block diagrams that had been created. Simulation is carried out to make sure the simulation block is working as expected based on its characteristics and capabilities.

For the hardware implementation, a three phase inverter is design using specific software and the fabricated. The electronic parts that needed will be soldered onto the board. The gate driver and the DSP board will be provided by the faculty during the experiment.

1.5 Thesis Outline

This thesis is consisting of five chapters. Chapter 1 is mainly about the background, objectives and the significant of the project. It also describing the control technique used in inverter and existence of harmonics in general.

Chapter 2 describes the studies of inverter, it modulation techniques and application of inverters in real life. This chapter discussed the details of the control technique used in the project.

Chapter 3 provides the methodology used in for the project. It includes all the software and hardware used in every step. Every software and hardware are described in detail for the project design.

Chapter 4 is all about the result and analysis of the study. This chapter includes the relevant graphs and analysis for comparison purposes. The results obtained is discussed in this part.

Chapter 5 summarises and concludes the findings of the project. It also includes some recommendation for future improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 Inverter

Inverter is one of the significant part in electrical and electronic. Inverter exist for power conversion from DC to AC. AC and DC source exist in the late 19th century.[5] During that period, a battle called the War of Currents broke out between the two brilliant inventors, Tesla and Edison.[6] AC system won the battle however since the DC system was implemented earlier, hence both system still being used depending on the condition until today. To integrated both sources, a converter is needed. Converting an AC source to DC source needs rectifier while converting DC to AC source needs an inverter.

Inverter can be classified by it input source, voltage source input (VSI) and current source input (CSI). VSI as the name stated, it takes in a fixed voltage from the DC supply and converts it to a variable-frequency AC supply.[7] CSI takes in variable current from DC supply that has high impedance. VSI have proven to be more efficient, and cost effective. [4]

In VSI, the output voltage can be control and the output waveform should not be depend on the load connected to the inverter.[8] Compare to VSI, CSI are far more less developed topology in power electronic conversion. However, CSI do offer some advantages such as voltage boost, short circuit protection, reduced electromagnetic interference and direct regeneration.[9]

Alternating current as the name mention, it has a positive and negative magnitude to form a sine wave. DC where the source only flows in one direction, is converted to AC needs a switch that can turn on and off with high speed which is 50 times per second to produce AC with frequency of 50Hz.

Inverter again divided to two categories; single phase inverter and three phase inverter. Single phase inverter again can be divided into two types, single-phase half

bridge inverter and single-phase full bridge inverter. Single-phase inverter will produce single sinusoidal where three phase inverter will produce three sine wave with a phase shift based on the control system of the switches.

2.2 Three Phase Inverter

Three phase inverter as the name indicate, the inverter will produce three phase AC source instead of single phase. Three phase inverter has six switch that will alternately switch based on the control system used to control the switching. The semiconductor switches used can be transistor, thyristor, metal-oxide-semiconductor field-effect transistor (MOSFET), or insulated gate bipolar transistor (IGBT). A typical three phase inverter, specifically two-level inverter has six switches. The switches labelled as S1 to S6. This three phase inverter required a full bridge topology to produce three phase outputs. Each leg consists of two power switches. The six power switches can be constructed using BJTs, IGBT, and any possible switches as stated before that suite the operating voltage, has tolerance to high switching frequency, and has low power loss. [4]

Three phase inverter works as an upper power switch is switched on, the lower power switch is switched off. Hence, changing of the state from ON to OFF and vice versa of the power switches can be used to control the current output voltage. In three phase inverter, power switches of same leg cannot be switched on and off simultaneously.

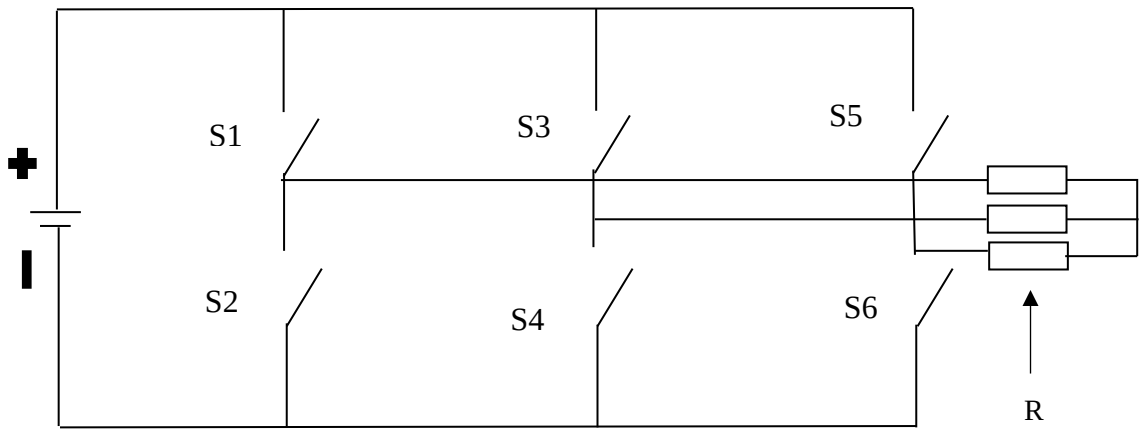

Figure 2. 1 Core structure of a simple three phase inverter

2.3 Pulse Width Modulation (PWM)

Recently, PWM has been used widely due to wide application of voltage source inverters in AC power generation. PWM methods are based on fixed amplitude pulses. PWM technique has been proven to easily control of output voltage and minimized the lower order of harmonics since the higher harmonics can be filter easily.[7], [10], [11] Different type of PWM methods have been discovered and proven to obtain a large linear modulation range, lower switching loss, lower total harmonic distortion (THD), easy implementation and less computation time.[12] There are few type of commonly used PWM technique; [13]–[15]

i. Single pulse width modulation
ii. Multiple pulse width modulation
iii. Sinusoidal pulse width modulation (SPWM)
iv. Space vector pulse width modulation (SVPWM).
v. Third harmonic injection pulse width modulation

2.3.1 Working Principle of PWM

PWM is a modulation technique to encode message or information into a pulsing signal. PWM operates like a switch where it constantly on and off based on the duty cycle. Figure 2.2 is the duty cycle. When DC source is injected into the inverter, the input is "chopped" by means of switching devices in the inverter.[12] The switching devices can be bipolar transistor, thyristors, MOSFET, IGBT and so on. As stated before, the amplitude and AC wave form are regulated by the duty cycle. PWM is a method to get analog results with digital means. Digital control is applied to generate a square wave based on the switching states of the switches. Output of PWM signal is generate from the comparison of the two different signals. From Figure 2.3, the two signals are modulating signal (sinusoidal wave) and carrier signal (saw tooth wave). Comparator is involved in the comparison process. The frequency size of PWM output signal is varying based on the size of intersection between carriers and modulating signal.